Management of Changing to PBL at the Faculty of Engineering of Universidad Nacional de Colombia

***Abstract*– The Faculty of Engineering of the Universidad Nacional de Colombia, led by its directives, began three years ago the implementation of strategies for the management of change, seeking to transform their methodologies and pedagogical practices into active learning, student-centered and PBL. This paper details the top-down and bottom-up strategies applied in the Faculty and the results obtained so far.**

Keywords—Management of changing, engineering education, Project Based Learning, Flipped classroom.

I. Introduction

The Faculty of Engineering of the Universidad Nacional de Colombia with its 158 years of history is highly recognized nationally and internationally for its academic excellence, tradition, historical influence, scientific production and for the professional and human qualities of its graduates.

In its nine undergraduate programs, sixteen master and seven doctoral programs, approximately 7000 students are enrolled. According to its public nature, most of students belong to the lower socioeconomic segments of the Colombian society.

Throughout its history, the Faculty has gone through at least three particular junctures in which the participation of the academic community in reflections and analysis on methodologies, instructional tools and strategies in higher education, led to significant changes in these aspects. The exchange of ideas and the enthusiasm of each one of these historical contexts, where summarized in the so-called "academic reforms", being the last of them, that of the year 2008 whose guidelines and regulations still apply today to the Universidad Nacional de Colombia.

In this work, it is related how the identification of a new historical context within the Faculty of Engineering, led the academic community towards the adoption of top-down as well as bottom-up change strategies, which lead to the transformation of teaching-learning processes, the implementation of interventions regarding active learning methodologies, and Project-Based Learning (PjBL), opening the way for a potential implementation of Problem-Based Learning (PBL) in a single courses.

II. Management of Changing to PBL

As De Graaff and Kolmos [1] affirm, "*higher engineering education is a field with strong traditions*". The need to a transformation from traditional to a student-centered learning approach is widely reported in education PBL literature. De Graaff and Kolmos [2] explain the causes of the paradigm shift in the need to encourage learning, improve institution image, reduce dropouts rates and support advancement of emerging competencies. However, Fullan as cited in De Graaff and Kolmos [2], asserts that change is a process and not an event; does not happen overnight but its influence is comprehensive.

Below are explained the guidelines and actions adopted by the Faculty that allowed the development of strategies at the system and at the individual levels, including the analysis of the particularities of the Faculty to identify the context in which a PBL methodology could be implemented and the diagnosis of the learning strategies applied by the students. As Kolmos says [3] neither of both strategies when implemented in isolation, can guarantee a sustainable change, "*however, the two strategies supplement each other and make change possible*." (p.3).

Institutional change encompasses planning with clear identification of short-term and long-term objectives. Strategies that are applicable include empirical –rational, normative- re-educative and power-coercive strategies, each resting on the inherent belief of human nature. De Graaff and Kolmos [2] explain that empirical-rational strategy identifies human as rational and thus the interest in individual gain. Through this strategy, effecting change requires pointing out benefits. It is appropriate for effecting educational change. On the other hand, normative- re-educative identifies conservative nature of man and thus the need for cultural change to effect an organizational change. It is appropriate for long-term projects aimed at growth. Finally, power- coercive strategy diverts from the assumption that human is interested in personal gain or risks and thus a top-down leadership approach is necessary to effect change. The power-coercive strategy is best suited for organizations that need instant results but may not be suitable for long-term change particularly in education because it reset with a small team.

There are challenges involved in the change process. The innovations get lost when a faculty member initiating the desired change leaves because other colleagues are not willing to dedicate themselves to the course in a new way because the time commitment was bigger than for normal lectures. The model of change shows the independence traditionally enjoyed by faculty, making them initiate change in their own

Digital Object Identifier: (to be inserted by LACCEI).
ISSN, ISBN: (to be inserted by LACCEI).

program. Therefore, change emanates from the dissatisfaction of a single faculty member with an element of student performance or participation without any scientific strictness in its creation or impact assessment [4]. The case of the Engineering Faculty of the Universidad Nacional de Colombia try to develop a culture of collective responsibility using a set of top-down as well as bottom-up change strategies

II. Contextual and Cultural Aspects to Consider

Savin-Baden and Major [5] point out that in the development and application of a Problem Based Learning-PBL model or mode, it is important to analyse the context and culture in which the methodology will be applied.

Guzman and Takeuchi [6], analyzed the aspects related to the organizational culture and institutional normative of the Faculty and determined some aspects that would intervene in the potential implementation of PBL:

Diversity of students: students of Faculty of Engineering are representative of all the richness of Colombian diversity as socioeconomic origins, races, creeds, gender and sexual orientations.

Academic liberty: It is a principle highly valued but often misunderstood by some teachers who confuse it with the freedom not to follow guidelines emanated from the directives of the Faculty.

Traditions: the introduction of innovations and changes is a complex goal. It is to be expected that there will be a high resistance to change.

Difficult relationships with teachers from other faculties: teachers affiliated with the Faculty of Sciences, offer several fundamental subjects to Engineering students. Historically, these teachers apply some degree of independence with respect to the policies and suggestions from the Faculty of Engineering.

The size of the groups: at present it varies between 30 and 80 students per group.

Structure of curriculum plans: They are highly flexible, lack prerequisites and allow multiple routes.

Dropouts of courses: The student regulation, allows students to withdraw from a course during the first half of the academic semester.

As conclusion, authors in [6] say:

"*It is advisable in a novel implementation, to consider modes of active learning that imply:*

- Participation and integration of the students.

- The implementation of the intervention in a subject will not be affected by the other subjects in which each student is enrolled Involve one subject of the curriculum plan.

- Possibility to be implemented in a group without requiring coordination with other teachers who offer the same subject or other subjects.

- Independence on the participation of teachers of the foundation component subjects (professors of the Faculty of Sciences).

- Be applicable regardless of the size of the groups requiring modest investments

- A gradual transformation of traditional pedagogical practices maintaining some lectures or written exams." (p. 29)

III . Management of Changing to PBL

A. *Change at the system level: Top-down strategy*

Teacher's formation: Due to the interest and support of the Faculty's top management in promoting a change in teaching-learning methodologies and a transformation of pedagogical practices, the formation of a seed group of teachers was planned, in master's studies related to education in engineering.

The selected program was the Master in Problem Based Learning for Engineering and Sciences at Aalborg University.

Through an open call to all professors of the Faculty, six volunteer professors, all of them with a doctorate degree, accepted to start the master's program in the second semester of 2016. A new call was opened in 2017, to which four other teachers enrolled.

Simultaneously training courses have been offered to another 40 teachers, all related to curricular redesign, active learning and PBL.

Diagnosis: As part of this strategy, the diagnosis of the learning strategies applied by the students was financed [7]. This work showed that students have relevant skills such as teamwork, they almost do not apply strategies that leads them the organization of ideas or the management of their studying time.

Additionally, this strategy contributes to developing a culture of collective responsibility due to the impact to other colleagues. The experience of management of change process in the Faculty is summarized in a whole picture Fig. 1.

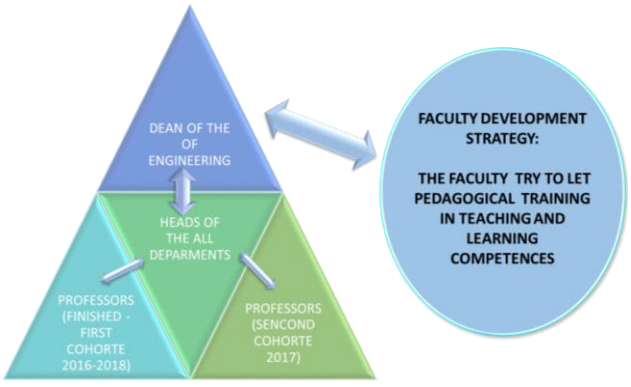

Figure 1- Engineering Faculty Strategy of the Management of Change process

B. Change at the individual level: Bottom-up strategy.

Framed by the development plan of the Faculty related with the project of "Innovation initiatives in teaching-learning processes in the Faculty of Engineering", the Bottom-up strategy supports the "small steps" and half models – lose the overall objectives, especially with the change of top management and satisfaction with the small steps, Fig. 2.

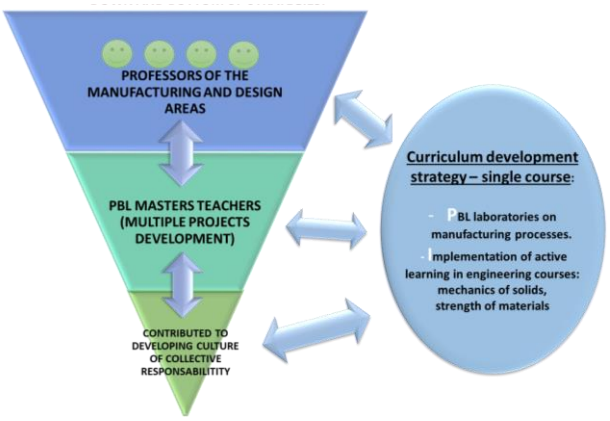

Figure 2- Top-down and Bottom-up strategies developed

As a result of the formation of teachers in the master's program, all of them have implemented interventions in the courses they offer. Next, three of these interventions are explained.

IV. IMPLEMENTATION IN SINGLE COURSES

A. PBL laboratories on manufacturing process:

The implementation start in 2016 with the study of learning perception derived from an ongoing PBL implementation in an undergraduate Mechanical and Mechatronics engineering, Herrera L.K et al. [8] to expected to contribute bridging the gap between academia and industry and is aimed students to attain a strong background and skills in materials science, design engineering, scientific communication and project management [9].

The experiments were designed and conducted as a part of the research methodology to evaluate the learners' perception of the implemented PBL approach, according to Deming´s PDCA cycle (Plan, Do, Check and Act) . The first implementation showed to have a marked positive effect on learning, promoting the development of professional skills, demanding, in contrast, essential time-consuming requirements, especially in the laboratory practices, to achieve the expected learning outcomes [8].

According to these results, the facilitator was motivated to created new learning tools to reduce the time-consuming related to the laboratory practices.

Virtual laboratories with PBL methodology has sought the implementation of teaching tools as VOL (Virtual Object Learning) with the purpose to develop the learning process related to manufacturing processes course, to link the knowledge acquired by students in the theoretical classes. The student achieves the understanding of the implementation of the manufacturing processes of engineering components as the improvement of the quality of the manufacturing products from the creation of new materials and processes applied to a real environment.

The facilitators achieving that the student can identify the mechanisms of scientific and technological innovation from the interdisciplinary nature of materials science and the processes of manufacture.

B. Implementation of Flipped Classroom is Statics course.

Considering that Statics is a gatekeeper course with high enrolment and failure rates above 20%, Guzman, Sanchez and Takeuchi [10] decided to implement a Flipped Classroom approach for this course, hoping to obtain positive impacts on students learning. Flipped Classroom is defined as "*a form of blended learning that moves significant instruction and preparation outside the classroom to facilitate 'in class' time to be used for more participative learning activities"* [11] (p.1) and "*represents a unique combination of learning theories once thought to be incompatible active, problem-based learning activities founded upon a constructivist ideology and instructional lectures derived from directs instruction methods founded upon behaviourist methods*" [12] (p.1).

The second semester of 2017 a Flipped Classroom intervention in the Statics course, was applied in some groups for the first time. Then, in the first semester of 2018, the implementation was adapted taking into account the experience of the previous semester.

It is important to point out that before each intervention, great efforts were made and a lot of time was invested in the planning of the activities and the elaboration of the audio-visual materials, including the development of a Virtual Learning Object, which are the basis of this type of intervention.

To analyse to what extent the intervention impact the Students' success rates and motivation, a sequential explanatory mixed method design, was used. The research design consisted of collecting and analysing quantitative and qualitative data, integrating both forms of data. It was found that the intervention had a positive impact on the motivation of the

students and the failure rates decreased in the intervention group.

C. Implementation of Project Based Learning in Strength of Materials course.

For this subject, which is also considered a gatekeeper course by engineering students from around the world, the intervention implemented was Project Based Learning. (PjBL) approach "*is one that focuses on organizing self-learning in an empirical project. Through practical activities, interactive discussions, independent operation and/or team cooperation, students reach the planned target and establish their own know-how*" [13] (p.88) and "*PjBL provides the contextualized, authentic experiences necessary for students to scaffold learning and build meaningfully powerful science, technology, engineering, and mathematics concepts supported by language arts, social studies, and art. STEM PjBL is both challenging and motivating*" [14] (p.2).

As a fundamental part of the intervention, the students, through teamwork, developed three short design projects throughout the semester. All projects fulfil the following characteristics:

- Students must use modern engineering tools to solve the problem.
- Include computer programming tasks.
- Ill-ended assignments with a variety of possible solutions.

The working groups had two weeks to develop each project in extra class hours and the assessment of each project included a written report, oral statement of the report and a peer-review.

To evaluate the impact of the intervention on student performance, the same research design described in the previous section was used. The intervention showed a significant positive effect in the success rates and motivation.

CONCLUSIONS

According to the achievements of the Faculty after two years of application of the Top-down strategy for management of change, it can be concluded that the immediate goal of forming a group of teachers to act as agents of change was reached, and considerable progress has been made in the knowledge and dissemination of active learning methodologies, student-centered.

In terms of bottom-up strategies, these same teachers, as part of their work as agents of change, decided to implement different interventions in their own courses, with promising results. Their efforts can contribute to the collection of evidence that helps spread the benefits of active learning among colleagues who have not yet implemented it.

ACKNOWLEDGMENT

This study was performed with resources obtained from Engineering Faculty. The authors would thank the Universidad Nacional de Colombia for the financial support provided to enrol the Aalborg University Master of PBL.

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